

COOLING SYSTEM FOR A TURBINE VANE

FIELD OF THE INVENTION

This invention is directed generally to turbine vanes, and more particularly to
5 hollow turbine vanes having cooling channels for passing cooling fluids, such as air,
to cool the vanes and supply cooling fluids to the manifold of a turbine assembly.

BACKGROUND

Typically, gas turbine engines include a compressor for compressing air, a
10 combustor for mixing the compressed air with fuel and igniting the mixture, and a
turbine blade assembly for producing power. Combustors often operate at high
temperatures that may exceed 2,500 degrees Fahrenheit. Typical turbine combustor
configurations expose turbine vane and blade assemblies to these high
temperatures. As a result, turbine vanes and blades must be made of materials
15 capable of withstanding such high temperatures. In addition, turbine vanes and
blades often contain cooling systems for prolonging the life of the vanes and blades
and reducing the likelihood of failure as a result of excessive temperatures.

Typically, turbine vanes are formed from an elongated portion forming a vane
having one end configured to be coupled to a vane carrier and an opposite end
20 configured to be movably coupled to a manifold. The vane is ordinarily composed of
a leading edge, a trailing edge, a suction side, and a pressure side. The inner
aspects of most turbine vanes typically contain an intricate maze of cooling circuits
forming a cooling system. The cooling circuits in the vanes receive air from the
compressor of the turbine engine and pass the air through the ends of the vane
25 adapted to be coupled to the vane carrier. The cooling circuits often include multiple
flow paths that are designed to maintain all aspects of the turbine vane at a relatively
uniform temperature. At least some of the air passing through these cooling circuits
is exhausted through orifices in the leading edge, trailing edge, suction side, and
pressure side of the vane. A substantially portion of the air is passed into a manifold
30 to which the vane is movable coupled. The air supplied to the manifold may be
used, among other uses, to cool turbine blade assemblies coupled to the manifold.
While advances have been made in the cooling systems in turbine vanes, a need still

exists for a turbine vane having increased cooling efficiency for dissipating heat and passing a sufficient amount of cooling air through the vane and into the manifold.

SUMMARY OF THE INVENTION

5 This invention relates to a turbine vane having a cooling system including a convergent flow channel for receiving cooling fluids from a shroud assembly and passing a portion of the cooling fluids to one or more impingement channels in a leading edge cooling cavity and allowing the remainder of the cooling fluids to pass through a serpentine cooling path before being exhausted through exhaust orifices in
10 the trailing edge of the turbine vane. The cooling system has the capacity to sufficiently cool the turbine vane without requiring external film cooling orifices.

 The turbine vane may be formed from a generally elongated hollow airfoil having a leading edge, a trailing edge, a pressure side, a suction side, a first end adapted to be coupled to a shroud assembly, and a second end opposite the first
15 end adapted to be coupled to a manifold assembly. The convergent flow channel may include an inlet generally at the first end of the airfoil and may extend toward the second end of the airfoil. The convergent flow channel may have a first cross-sectional area proximate to the first end of the airfoil that is larger than a second cross-sectional area of the convergent flow channel closer to the second end of the
20 airfoil than the first cross-sectional area. This configuration of the convergent flow channel enables the cooling system to regulate flow of cooling fluids into the manifold assembly and to prevent overheating of the trailing edge of the vane.

 The turbine vane may also include a plurality of impingement channels extending from the convergent flow channel toward the leading edge and terminating
25 in a leading edge cooling cavity aft of an inner surface of the leading edge in a leading edge cooling cavity. The impingement channels may vary in length such that a first channel located closest to the first end of the airfoil may be shorter than a second impingement channel closest to the second end of the airfoil. In at least one embodiment, each impingement channel may terminate at a substantially similar
30 distance from the inner surface of the leading edge to maintain high impingement jet velocity and high impingement cooling effectiveness. This configuration is achieved by increasing the length of each impingement channel moving from the first end of

the airfoil to the second end of the airfoil. The cross-sectional area of each impingement channel may be substantially equal or may vary. Likewise, the distance between each impingement channel may be substantially equal or may vary as well.

5 In at least one embodiment, one or more of the plurality of impingement channels may be positioned within the leading edge cooling cavity using one or more pin fins. The pins fins may extend from an inner surface of the suction side of the vane and attach to an impingement channel or may extend from the inner surface of the pressure side of the vane and attach to the impingement channel, or both. In at
10 least one embodiment, each of the impingement channels is held in position using pin fins. The pin fins increase the surface area available for convection, thereby increasing the cooling capacity of the cooling system.

 In at least one embodiment, the convergent flow path forms a portion of a serpentine cooling path in an aft portion of the turbine vane. The serpentine cooling
15 path may have numerous passes, which in at least one embodiment may number three passes. The serpentine cooling path may be in communication with one or more exhaust orifices in the trailing edge of the turbine vane for exhausting cooling fluids from the vane.

 In operation, a cooling fluid enters the cooling system from a shroud
20 assembly through one or more inlets in the first end of the turbine vane. The cooling fluid enters the convergent flow channel and, a substantial portion of the cooling fluid is then bled off of the convergent flow channel through the impingement channels. The cooling fluid flows through the impingement channels and impinges against the inner surface of the leading edge. The cooling fluid then flows through the leading
25 edge cooling cavity and is exhausted to the manifold assembly. The cooling fluids remaining in the convergent flow channel is passed through a serpentine cooling path and exhausted through one or more exhaust orifices in the trailing edge of the blade.

 An advantage of this invention is that the cooling system is capable of
30 removing sufficient heat without necessitating external film cooling.

 Another advantage of this invention is that the leading edge cooling cavity may be configured as a divergent cooling cavity, which minimizes cross flow of the

cooling fluids passing through impingement channels proximate to the first end of the airfoil.

Yet another advantage of this invention is that the pin fins increase the cooling capacity of the cooling system.

5 These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the presently disclosed invention and,
10 together with the description, disclose the principles of the invention.

Figure 1 is a perspective view of a turbine vane having features according to the instant invention.

Figure 2 is cross-sectional view of the turbine vane shown in Figure 1 taken along line 2-2.

15 Figure 3 is a cross-sectional view of the turbine vane shown in Figures 1 and 2 taken along line 3-3 in Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figures 1-3, this invention is directed to a turbine vane 10 having
20 a cooling system 12 in inner aspects of the turbine vane 10 for use in turbine engines. The cooling system 12 is configured such that adequate cooling occurs internally without using external film cooling from cooling fluids supplied through orifices in the housing forming the vane 10. In particular, the cooling system 12 includes at least one convergent flow channel 14 for receiving a cooling fluid from a
25 shroud assembly 16, and may include one or more impingement channels 18 proximate to a leading edge 20 for directing cooling fluids to contact an inner surface 22 of the leading edge 20. In at least one embodiment, the convergent flow channel 14 may be a serpentine cooling path 24, which directs a cooling fluid through one or more exhaust orifices 26 in a trailing edge 28 of the turbine vane 10.

30 As shown in Figure 1, the turbine vane 10 may be formed from a generally elongated airfoil 30 having an outer surface 32 adapted for use in an axial flow turbine engine. Outer surface 32 may be formed from a housing 34 having a

generally concave shaped portion forming pressure side 36 and may have a generally convex shaped portion forming suction side 38. The turbine vane 10 may also include a first end 40 adapted to be coupled to the shroud assembly 16 and a second end 42 adapted to be coupled to a manifold assembly 44.

5 As shown in Figure 2, the convergent flow channel 14 may have a first cross-sectional area 46 proximate to the first end 40 of the airfoil 30 that is larger than a second cross-sectional area 48 closer to the second end 42 of the airfoil 30 than the first cross-sectional area 46. In at least one embodiment, the convergent flow channel 14 may extend from the first end 40 of the airfoil 30 to a second end 42 of the airfoil 22. In other embodiments, the convergent flow channel 14 may not extend the entire length between the first and second ends 40, 42. In at least one embodiment, the convergent flow channel 14 may be a first inflow section 52 of the serpentine cooling path 24. The serpentine cooling path 24 may also include a first outflow section 54 and a second inflow section 56 forming a three-pass serpentine cooling path. The serpentine cooling path 24 is not limited to a three-pass system, but may have additional or fewer flow paths. Exhaust orifices 26 may be positioned in the trailing edge 28 and provide a pathway for cooling fluids to be exhausted from the second inflow section 56. In at least one embodiment, the serpentine cooling path 24 may include trip strips 64 for mixing cooling fluids as the cooling fluids flow through the serpentine cooling path 24 and for increasing the amount of heat removed from the turbine vane 10.

The convergent flow channel 14 may be formed from at least one rib 50 positioned between the leading edge 20 and the convergent flow channel 14. The rib 50 may be positioned in a generally nonparallel position relative to the leading edge 20, which forms a divergent leading edge cooling cavity 68. The divergent leading edge cavity 68 receives cooling fluids from the impingement channels 18. The divergent leading edge cooling cavity 68 minimizes the cross flow effect of cooling fluids flowing parallel to the inner surface 22 of the leading edge 20 and thereby, maximizes heat transfer at the inner surface 22. The rib 50 may include one or more orifices 51 to which the impingement channels 18 may be coupled. In at least one embodiment, as shown in Figure 2, the rib 50 may include a plurality of orifices 51 to which impingement channels 18 may be coupled. One or more

impingement channels 18 may extend from the rib 50 to towards an inner surface 22 of the leading edge 20. In at least one embodiment, the impingement channels 18 may terminate in the divergent leading edge cooling cavity 68 aft of the inner surface 22 of the leading edge 20. Each impingement channel 18 may terminate at a

5 substantially equal distance from the inner surface 22 of the leading edge 20, which allows cooling fluids flowing through the impingement channels 18 to maintain a high impingement jet velocity and impingement cooling effectiveness. The impingement channels 18 may have substantially equal cross-sectional areas or may have cross-sectional areas having difference sizes. The impingement channels 18 may be

10 spaced apart at substantially similar distances or at equal distances.

In at least one embodiment, as shown in Figure 2, the turbine vane 10 may include a plurality of impingement channels 18 extending between the rib 50 and the leading edge 20 and positioned from the first end 40 of the airfoil 30 to the second end 42 of the airfoil 30. The impingement channels 18 regulate the flow of cooling

15 fluids through the turbine vane 10 and prevent overflow of cooling fluids to the manifold assembly 44. By preventing overflow to the manifold assembly 44, the possibility of overheating portions of the housing 34 proximate to the trailing edge 28 is reduced. The impingement channel 18 positioned at the first end 40 may have the shortest length of the impingement channels 18 positioned between the first and

20 second ends 40, 42. The impingement channels 18 may increase in length proceeding from the first end 40 to the second end 42. In other words, each impingement channel 18 may be longer than the impingement channel 18 immediately adjacent to the channel 18 and closer to the first end 40 of the airfoil 30. The impingement channels 18 may be positioned at a substantially equal distance

25 from each other or may be positioned a varying distances from each other.

In at least one embodiment, the impingement channels 18 may be held in position between an inner surface 58 of the suction side 38 and an inner surface 60 of the pressure side 36 using one or more pin fins 62. One or more of the

30 impingement channels 18 may be supported by a pin fin 62 positioned between an inner surface 60 of the pressure side 36 and the impingement channel 18, or positioned between an inner surface 58 of the suction side 38 and the impingement

channel 18, or both. The pin fins 62 increase the surface area of the housing 34 and thereby increase the amount of convection surfaces.

In operation, a cooling fluid enters the cooling system 12 through an inlet 66 in the convergent flow channel 14. The inlet 66 may be sized and configured to
5 regulate the flow of cooling fluids into the convergent flow channel 14. The cooling fluids are bled into the impingement channels 18 from the convergent flow channel 14. The cooling fluids flow through the impingement channels 18 and are exhausted into the leading edge cool cavity 68. The cooling fluids impinge against the inner
10 surface 22 of the leading edge 20. The cooling fluids then flow through the leading edge cooling cavity 68 to the manifold assembly 44. In at least one embodiment including a divergent leading edge cooling cavity 68, the negative effects of cooling fluid cross flow is reduced to the point of being almost negligible because the cavity 68 increases in cross-sectional area as additional cooling fluid is emitted from each
15 impingement channel 18, moving from the first end 40 to the second end 42 of the airfoil 30. Thus, cross-flow velocity is maintained at a substantially steady rate. Cooling fluids not flowing into the impingement channels 18 continue to flow through the serpentine cooling path 24 and are exhausted through the exhaust orifices 26. The amount of cooling fluids flowing through the turbine vane 10 and into the manifold assembly 44 is controlled by the number and cross-sectional areas of the
20 impingement channels 18.

The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of this invention.